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<p><b>(54) Title:</b> DEVICE FOR EQUALIZING PRESSURE ACROSS THE EARDRUM OF DIVERS</p> <p><b>(57) Abstract</b></p> <p>A device for facilitating the equalization of pressure across the eardrum of a user, comprising (a) a mask body configured to closely fit the face of the user so as to cover at least the eyes and nose of the user, so that, when in use, the mask body and the face of the user define a first closed space, the mask including a transparent window through which the user sees; (b) first and second ear cups for closely covering the ears of the user, the ear cups and the sides of the head of the user define second and third closed spaces around the ears of the user, respectively; (c) first and second tubes extending from the mask body, each of the first and second tubes having a first end and a second end, the first ends communicating with the first closed space defined by the mask body and the face of the user, the second ends communicating with the second and third closed spaces, respectively, defined by the ear cups and the sides of the head of the user; (d) a strap arrangement connecting between each of the first and second ear cups and the mask body and between the first and second ear cups; and (e) an adjusting and supporting mechanism associated with the strap arrangement for adjusting the position of the ear cups with respect to the ears of the user and for tightly supporting the mask body and the ear cups in their respective positions onto the head of the user.</p>			

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DEVICE FOR EQUALIZING PRESSURE ACROSS THE  
EARDRUM OF DIVERS

FIELD AND BACKGROUND OF THE INVENTION

5       The present invention relates to underwater diving equipment and, more particularly, to devices for facilitating the equalization of pressure between the diver's middle and outer ear.

As shown in Figure 1, the human ear is made up of three sections, commonly designated the outer ear, the middle ear and the inner ear. The 10 outer ear includes the portion of the ear from the eardrum 10 outward to the ear opening. The inner ear includes the cochlea 12 and the three semi-circular canals 14. The middle ear is that portion of the ear between the eardrum 10 and the inner ear.

The middle ear is connected to the mouth cavity (not shown) 15 through the eustachian tube 16, whose chief function is to equalize the pressure between the middle ear and the mouth cavity (typically the ambient pressure). Thus, under normal conditions, whenever the ambient pressure rises, the pressure in the outer ear rises, as does the pressure in the mouth cavity. The rise in pressure in the mouth cavity brings about a 20 concomitant rise in the middle ear through the eustachian tubes. The result is adequate pressure equalization between the outer and middle ear across the eardrum (see Figure 2).

The pressure equalization is particularly important for divers since the ambient pressure changes dramatically and rapidly as the diver lowers 25 himself beneath the water surface or rises toward the water surface.

The pressure equalization may be delayed or prevented when secretions block the eustachian tubes (see Figure 3). This may be the case when the diver's eardrum is excited by low temperatures, water or pressure which brings about edema with its excessive secretion from the

mucous membranes surrounding the middle ear and the eustachian tube. The edema furthermore narrows the eustachian tubes.

Furthermore, when diving the pressure on the outer ear increases almost instantaneously while the pressure in the middle ear increases at a  
5 lower rate, because of the narrowness of the eustachian tubes, which causes, for a short time, a relative under-pressurized condition in the middle ear. This under-pressure can stimulate the secretion of mucous and blood from the tissue surrounding the middle ear and eustachian tube and could lead to the blockage of the eustachian and the prevention of  
10 further pressure stabilization.

The result of a pressure differential between the outer and middle ear can vary from discomfort to great pain and could, in some cases, lead to the rupture of the eardrum.

Additionally, it is desirable to prevent the entry of cold water into  
15 the ear, which could result in loss of balance, stimulated ear mucous and blood secretions and bacterial infections.

To prevent the pressure equalization and related difficulties, it has been proposed to prevent entrance of water into the ear and to provide external tubes which functionally supplement the eustachian tubes and  
20 which serve to equalize the pressure across the eardrum.

U.S. Patent No. 4,896,380 discloses a facemask which is equipped with a pair of tubes. Each tube features an earplug at its far end. Each of the earplugs can be plugged into the ear canal and air from the facemask is able to reach the outer ear through the tube in order to equalize the  
25 pressure across the eardrum. A disadvantage of such a system is that the air pressure from the mask is transferred directly to the outer ear without any delay or attenuation which could cause the user considerable discomfort. In addition, the earplugs tend to get dislodged from the ears during a dive, which leads to loss of air and discomfort. A further

disadvantage is that upon dislodging of one of the tubes would create a significant pressure difference in the two ears which could greatly inconvenience the diver.

U.S. Patent 2,488,235 also discloses an underwater facemask  
5 equipped with a pair of tubes. Each tube communicates at its far end with a substantially semi-spherical ear cup which covers the user's ear. The strap of the facemask serves to push the ear cups toward the user's ears. A disadvantage of such a system is that the strap securing the facemask to the face of the diver and the ear cups are essentially separate units so that  
10 the strap exerts inward pressure on the ear cups without relation to the ambient water pressure which destroys any chance of fine tuning the pressure on the user's ears, as described below. Furthermore, U.S. Patent 2,488,235 fails to disclose a mechanism for adjusting the position of the ear cups to a specific user.

15 U.S. Pat. No. 5,483,975 teaches a device for facilitating the equalization of pressure across the eardrum of a user which typically includes a facemask configured to fit over at least the eyes and nose of the user. The device further includes a strap for securing the facemask to the face of the user. The strap, when secured to the head of the user, defines  
20 a single air space which includes ear portions overlying the user's ears and a connecting portion overlying the sides and back of the user's head and connecting the ear portions. Finally, the device includes a tube for supplying air to the air space. One end of the tube is connected to the air space while the other end of the tube is connected to a source of  
25 pressurized air, such as the facemask, the air supply controller or the air supply mouthpiece. A disadvantage of such a device is that the strap is traditionally used for tightly securing the mask to the user's face, such that it becomes water impermeable. Such a device requires also adjustments of the ear portions, such that they fit the position of the ears

of a specific user. As further detailed below, a mechanism for adjusting the position of the ear portions and for further tightly securing the mask to the users face requires both front and rear adjustments. However, due to the function of the strap as a single air space providing a rear adjustment 5 is not feasible.

There is thus a widely recognized need for, and it would be highly advantageous to have, a simple and reliable device which will aid divers by equalizing the pressure between the outer and middle ear and between the two ears of the diver in a way which will minimize or eliminate 10 discomfort, which device is adjustable to the size of the user's head.

#### SUMMARY OF THE INVENTION

According to the present invention there is provided a device for facilitating the equalization of pressure across the eardrum of a user, 15 comprising (a) a mask body configured to closely fit the face of the user so as to cover at least the eyes and nose of the user, so that, when in use, the mask body and the face of the user define a first closed space, the mask including a transparent window throughwhich the user sees; (b) first and second ear cups for closely covering the ears of the user, the ear cups 20 and the sides of the head of the user define a second and third closed spaces around the ears of the user, respectively; (c) first and second tubes extending from the mask body, each of the first and second tubes having a first end and a second end, the first ends communicating with the first closed space defined by the mask body and the face of the user, the second ends communicating with the second and third closed spaces, respectively, defined by the ear cups and the sides of the head of the user; 25 (d) a strap arrangement connecting between each of the first and second ear cups and the mask body and between the first and second ear cups; and (e) an adjusting and supporting mechanism associated with the strap

arrangement for adjusting the position of the ear cups with respect to the ears of the user and for tightly supporting the mask body and the ear cups in their respective positions onto the head of the user.

According to still further features in the described preferred  
5 embodiments the mask body is large enough to cover the whole size of the face of the user.

According to still further features in the described preferred embodiments the strap arrangement includes first and second side straps connecting between the first and second ear cups and the mask body and a  
10 first and second rear straps connected to one another for connecting between the first and second ear cups.

According to still further features in the described preferred embodiments the strap adjusting and supporting mechanism includes (i) first and second side adjusting implements for controlling the functional  
15 length of the first and second side straps, respectively; and (ii) a rear adjusting implement for controlling the functional length of the first and second rear straps.

According to still further features in the described preferred embodiments the strap arrangement includes a single strap, the single  
20 strap is connected at both ends to the mask body, and wherein the adjusting and supporting mechanism includes (i) first and second translatable connectors connected or integrally formed with the first and second ear cups, respectively for translatable connecting the ear cups to the single strap for translatable adjustable to their respective positions;  
25 and (ii) first and second side adjusting implements for controlling the functional length of the single strap.

According to still further features in the described preferred embodiments at least a portion of each of the ear cups is formed as a diaphragm and wherein the connectors are formed as tough bridges, such

that during adjustment the diaphragm is substantially unaffected, so that during and following adjustment each of the second and third closed spaces retain their pressure.

According to still further features in the described preferred  
5 embodiments the device further comprising at least one audio device  
implemented in one of the ear cups.

According to still further features in the described preferred  
embodiments each of the ear cups includes a partition having an opening,  
the partition dividing the ear cups into a subspace adjacent the user's ear  
10 and a subspace removed from the user's ear, and wherein the second ends  
of the tubes are connected to the subspaces removed from the user's ears.

According to still further features in the described preferred  
embodiments at least a portion of each of the ear cups is formed as a  
flexible diaphragm.

15 According to still further features in the described preferred  
embodiments each of the ear cups includes a peripheral edge for sealing  
against the user's head sides.

According to still further features in the described preferred  
embodiments at least a portion of the peripheral edge is flared in the  
20 direction of the user's head, so as to form an inner and outer peripheral  
edges.

According to still further features in the described preferred  
embodiments the inner peripheral edge of each of the ear cups is formed  
with a groove for assisting in pumping water out of the ear cups.

25 The present invention successfully addresses the shortcomings of  
the presently known configurations by providing a simple and reliable  
device for facilitating the equalization of pressure across the user's  
eardrums which is particularly useful during undersea diving, which  
device is adjustable to the size of the user's head.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

5 FIG. 1 is a cross-sectional view of the human ear;

FIG. 2 is a schematic view of the human ear under pressure equalization;

FIG. 3 is a schematic view of the human ear with a blocked eustachian tube which prevents pressure equalization;

10 FIG. 4 shows a perspective view of one embodiment of a device according to the present invention;

FIG. 5 shows a top view of the device of Figure 4, wherein side and rear adjusting implements are employed for adjusting and supporting the device to the head of the user;

15 FIG. 6 shows a perspective view of the rear adjusting implement used with the embodiment shown in Figure 5;

FIG. 7 shows a top view of another embodiment of a device according to the present invention, wherein connectors are used to translate the ear cups to their ear covering position;

20 FIG. 8 is a side cross sectional view of the ear cup of a typical device according to the present invention;

FIG. 9 is an inner top view of the ear cup according to a preferred embodiment of the invention, wherein a recession is formed in the inner peripheral edge of the cup; and

25 FIG. 10 is a side cross sectional view of the ear cup of another embodiment of a typical device according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of a diving device which can be used to equalize pressure across the eardrum, which device is adjustable to fit the dimensions of the head of the user.

The principles and operation of a device according to the present  
5 invention may be better understood with reference to the drawings and the accompanying description.

Referring now to the drawings, Figures 4-5 depicts a basic embodiment of a device according to the present invention. In the preferred embodiments illustrated in the drawings, the device includes a  
10 mask body 20 which is configured to fit over at least the eyes and nose of the user, so that, when in use, mask body 20 and the face of the user define a first closed space 22. Mask body 20 includes a transparent window 24 throughwhich the user sees.

In figures 4-5 mask body 20 is shown to cover only the eyes and  
15 nose of the user, however a mask body which is large enough to cover the whole size of the face of the user is also within the scope of the present invention.

The device further includes first and second ear cups 26 for closely covering the ears of the user. Ear cups 26 overlay the ears of the user,  
20 therefore ear cups 26 and the sides of the head of the user define a second and third closed spaces 28, respectively, covering the ears of the user.

The device further includes first and second tubes 30 extending from mask body 20. Each of tubes 30 has a first end 32 and a second end  
34. First ends 32 of tubes 30 are in fluid communication with closed  
25 space 22 defined by mask body 20 and the face of the user. Whereas, second ends 34 of tubes 30 are in fluid communication with second and third closed spaces 28, respectively, defined by ear cups 26 and the sides of the head of the user. Thus, first 22, second and third 28 closed spaces are in fluid communication there amongst.

The device further includes a strap arrangement 36. Strap arrangement 36 is connecting between each of first and second ear cups 26 and mask body 30 and between first and second ear cups 26.

The device further includes an adjusting and supporting (tightening) mechanism 38. Mechanism 38 is associated with strap arrangement 36 for adjusting the position of ear cups 26 with respect to the ears of the user and for tightly supporting mask body 20 and ear cups 26 in their respective positions onto the head of the user.

According to one preferred embodiment of the invention strap arrangement 36 includes first and second side straps 40 connecting between first and second ear cups 26 and mask body 20. According to this embodiment strap arrangement 36 further includes first and second rear straps 42, connected to one another as further described below, for connecting between first and second ear cups 26.

Further according to this embodiment of the invention strap adjusting and supporting mechanism 38 includes first and second side adjusting implements 44 for controlling the functional length of first and second side straps 40, respectively, and a rear adjusting implement 46 for controlling the functional length of first and second rear straps 42. Figure 6, presents rear adjusting implement 46. In the example of Figure 6, implement 46 is formed as a plate 47 having two holes 49 at its edges for accepting rear straps 42. Straps 42 are formed with ridges 51 to be hooked by holes 49, as well known in the art. As shown in Figure 4, side adjusting implements 44 feature a similar construction.

According to another embodiment of the invention, as shown in Figure 7, strap arrangement 36 includes a single strap connected at both ends to mask body 20. According to this embodiment adjusting and supporting mechanism 38 includes first and second translatable connectors 50. Connectors 50 are connected to or integrally formed with first and

second ear cups 26, respectively, and are used for translatable connecting ear cups 26 to single strap 36 for translatable adjusting ear cups 26 to their respective positions at the sides of the head of the user. According to this embodiment. Further according to this embodiment adjusting and 5 supporting mechanism 38 further includes first and second side adjusting implements 44 for controlling the functional length of single strap 36.

Preferably, as shown in Figure 7, at least a portion 52 of each of ear cups 26 is made of relatively thin flexible material so as to allow these portions to serve as diaphragms for transmitting ambient water pressure to 10 spaces 28 defined by ear cups 26. The advantage of such a construction is that it makes it possible to take advantage of the ambient water pressure to fine-tune the pressure on the user's ear, a pressure which, in the absence of this fine-tuning, would be determined by the pressure provided by the mechanical pressure regulator. Furthermore, the use of a thin flexible 15 material makes it possible to take advantage of the elastic properties of the material as a buffer to delay the equalization of the pressures.

A further advantage of using a relatively thin flexible material for the ear cups 26 is that the use of such a thin diaphragm improves the diver's ability to hear underwater.

20 Connectors 50 are preferably formed as tough bridges 54, such that during adjustment of the device to the head of the user the qualities of membrane portions 52 are retained substantially unaffected, so that during and following adjustments of the device, each of second and third closed spaces 28 retain their pressure.

25 Other features of this embodiment, such as mask body 20, first closed space 22, transparent window 24, and tubes 30 mimic the features of the embodiment described hereinabove with respect to Figures 4 and 5.

According to both embodiments of the present invention the pressure across the eardrum of the user is equalized. This is due to air

supply controller 31 and mouthpiece 35, shown in Figure 4, which provide the breathing system of the user with air at a pressure substantially identical to the ambient water pressure, thereby closed spaces 22 and 28 and therefore the outer ear are all subjected to that pressure.

5 The middle ear, however, is also in communication with the breathing system of the user via the eustachian tube which connects the mouth cavity with the middle ear (see Figure 1).

Generally, the use of the device according to the present invention improves the quality of the sound as well as the sensing of the direction 10 from which the sound is emanating. Without in any way limiting the scope of the present invention, it is believed that the reason for the improvement in sound quality and directionality sensing is related to the fact that the present invention prevents water from surrounding the earlobe and entering the ear canal, which would tend to distort sound.

15 As shown in Figures 4-5 and 7, in a preferred embodiment of the invention the device further includes at least one audio device 60. Audio device 60 is used to play music or to provide audio instructions to the user. Device 60 is implemented in one or both ear cups 26. Miniaturized battery operated audio devices are well known devices formed as audio 20 chips which are widely used in computers and answering machines. Such devices are suitable both for repetitive recording of audio data and for playing any recorded data when desired. Positioning device 60 in ear cups 26 ensures that an air medium resides between device 60 and the ear of the user, such that high quality sound is achieved.

25 Shown in Figure 8 is a side cross-sectional view of ear cup 26. Preferably, the peripheral edge 29 of ear cup 26 which comes in contact with the user's head is flared in the direction of the user's head, as shown in Figure 8, so as to form an inner 31 and outer 33 peripheral edges, so as

to provide a better seal and prevent the leakage of air from closed space  
28 or water into that space.

Shown in Figure 9 is an inner top view of ear cup 26 according to a preferred embodiment of the invention. In this case inner peripheral edge 5 31 of each of each of ear cups 26 is formed with a groove 37 for assisting in pumping water out of said ear cups, when the device is worn underwater, following the common practice of divers.

Shown in Figure 10 is an alternative embodiment of ear cup 26. Here, each ear cup 26 includes a partition 70 which features a small 10 opening 72. Partition 70 divides ear cup 26 into two subspaces -- one adjacent the user's ear 28'' and a second subspace 28' which is removed from the user's ear. End 34 of tube 30 is connected to subspace 28' removed from the user's ear.

The purpose of partition 70 with its opening 72 is to retard in a 15 controlled manner the increase in pressure in ear cup 24 of the air space. Retarding the pressure increase prevents temporary under-pressure condition in the middle ear which reduces or eliminates the edema and secretions of the mucous in the middle ear.

The size of opening 72 is selected so that the pressure in the 20 subspace adjacent the user's ear does not rise instantaneously with increases in pressure in the removed subspaces but rather increases only gradually at a rate which is largely determined by the dimensions of opening 72. This mimics the rise in pressure in the middle ear due to the narrow diameter of the eustachian tube.

While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.

**WHAT IS CLAIMED IS:**

1. A device for facilitating the equalization of pressure across the eardrum of a user, comprising:
  - (a) a mask body configured to closely fit the face of the user so as to cover at least the eyes and nose of the user, so that, when in use, said mask body and the face of the user define a first closed space, said mask including a transparent window through which the user sees;
  - (b) first and second ear cups for closely covering the ears of the user, said ear cups and the sides of the head of the user define a second and third closed spaces around the ears of the user, respectively;
  - (c) first and second tubes extending from said mask body, each of said first and second tubes having a first end and a second end, said first ends communicating with said first closed space defined by said mask body and the face of the user, said second ends communicating with said second and third closed spaces, respectively, defined by said ear cups and the sides of the head of the user;
  - (d) a strap arrangement connecting between each of said first and second ear cups and said mask body and between said first and second ear cups; and
  - (e) an adjusting and supporting mechanism associated with said strap arrangement for adjusting the position of said ear cups with respect to the ears of the user and for tightly supporting said mask body and said ear cups in their respective positions onto the head of the user.

2. The device of claim 1, wherein said mask body is large enough to cover the whole size of the face of the user.

3. The device of claim 1, wherein said strap arrangement includes first and second side straps connecting between said first and second ear cups and said mask body and a first and second rear straps connected to one another for connecting between said first and second ear cups.

4. The device of claim 3, wherein said strap adjusting and supporting mechanism includes:

- (i) first and second side adjusting implements for controlling the functional length of said first and second side straps, respectively; and
- (ii) a rear adjusting implement for controlling the functional length of said first and second rear straps.

5. The device of claim 1, wherein said strap arrangement includes a single strap, said single strap is connected at both ends to said mask body, and wherein said adjusting and supporting mechanism includes:

- (i) first and second translatable connectors connected or integrally formed with said first and second ear cups, respectively for translatable connecting said ear cups to said single strap for translatable adjustable to their respective positions; and
- (ii) first and second side adjusting implements for controlling the functional length of said single strap.

6. The device of claim 5, wherein at least a portion of each of said ear cups is formed as a diaphragm and wherein said connectors are formed as tough bridges, such that during adjustment said diaphragm is substantially unaffected, so that during and following adjustment each of said second and third closed spaces retain their pressure.
7. The device of claim 1, further comprising at least one audio device implemented in one of said ear cups.
8. The device of claim 1, wherein each of said ear cups includes a partition having an opening, said partition dividing said ear cups into a subspace adjacent the user's ear and a subspace removed from the user's ear, and wherein said second ends of said tubes are connected to said subspaces removed from the user's ears.
9. The device of claim 1, wherein at least a portion of each of said ear cups is formed as a flexible diaphragm.
10. The device of claim 1, wherein each of said ear cups includes a peripheral edge for sealing against the user's head sides.
11. The device of claim 10, wherein at least a portion of said peripheral edge is flared in the direction of the user's head, so as to form an inner and outer peripheral edges.
12. The device of claim 11, wherein said inner peripheral edge of each of said ear cups is formed with a groove for assisting in pumping water out of said ear cups.

FIG.1

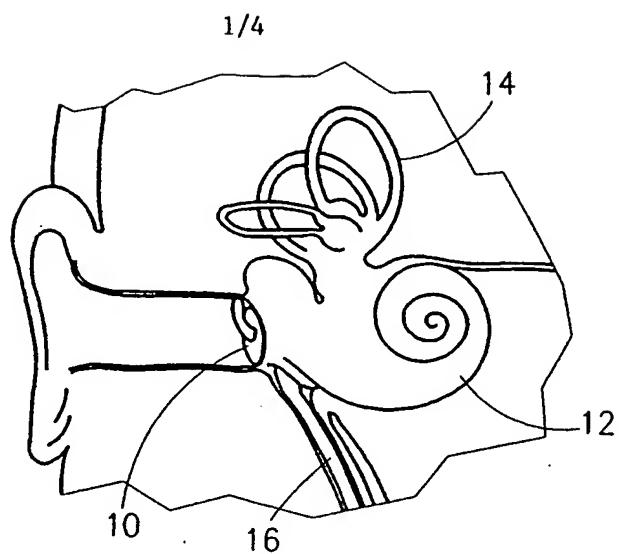


FIG.2

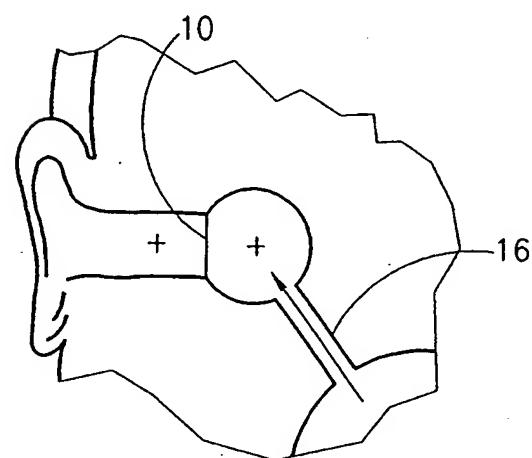
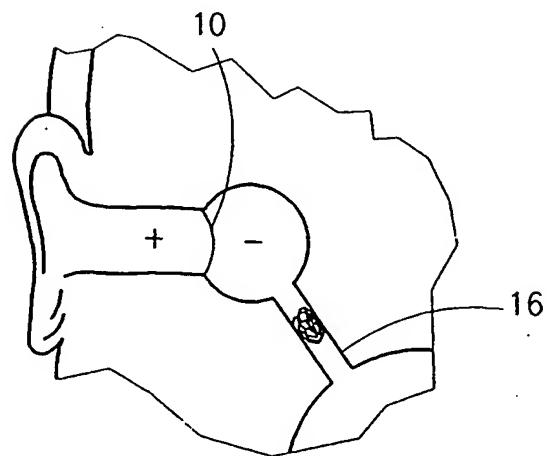


FIG.3



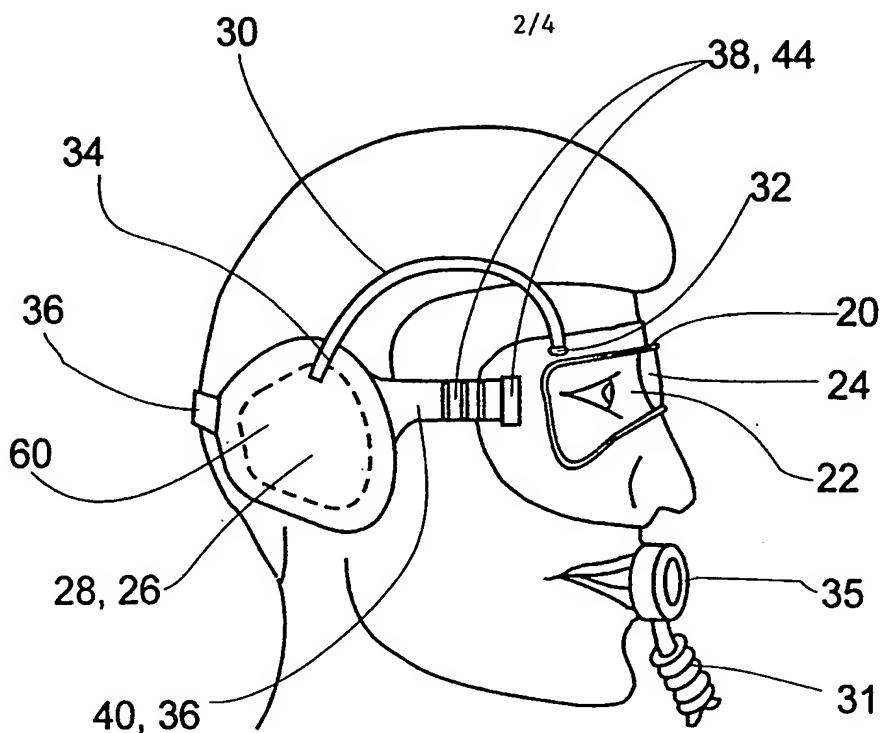


Fig. 4

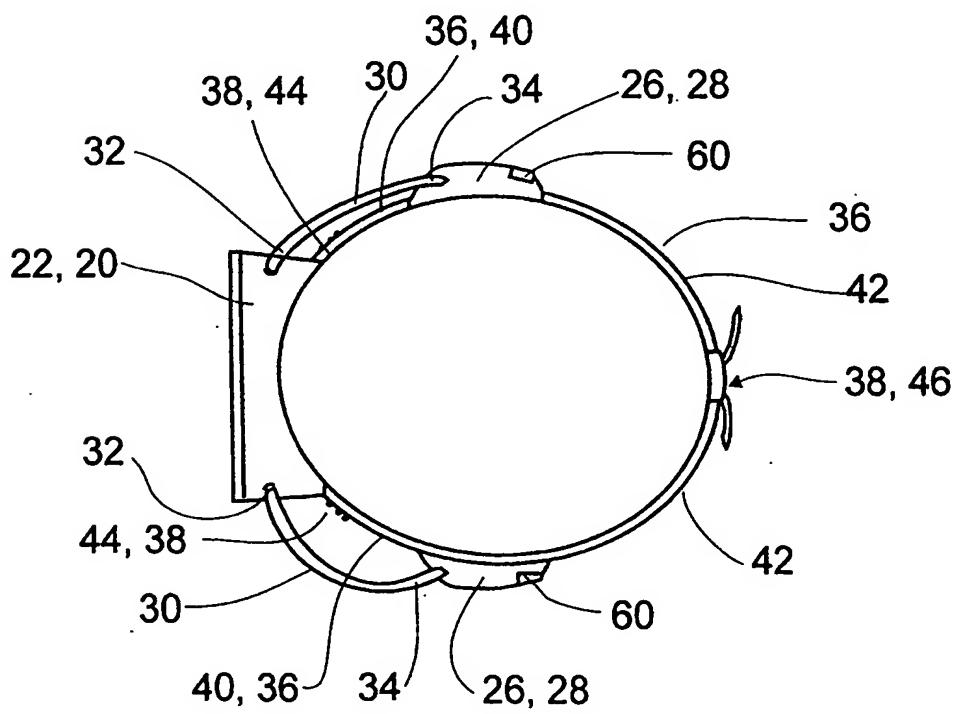


Fig. 5

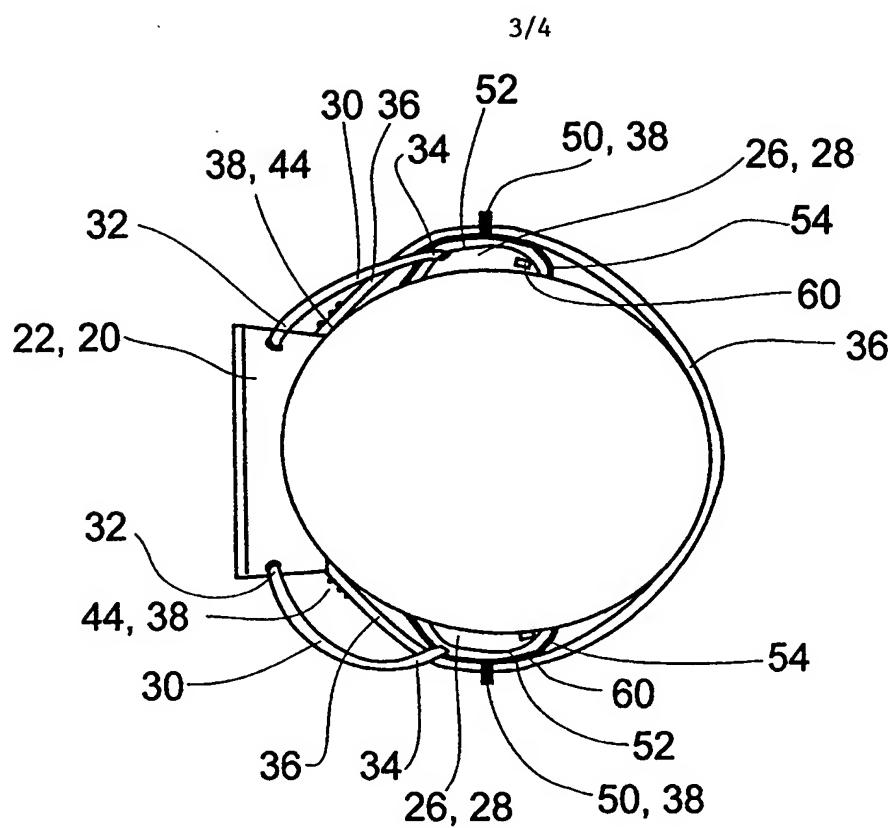


Fig. 7

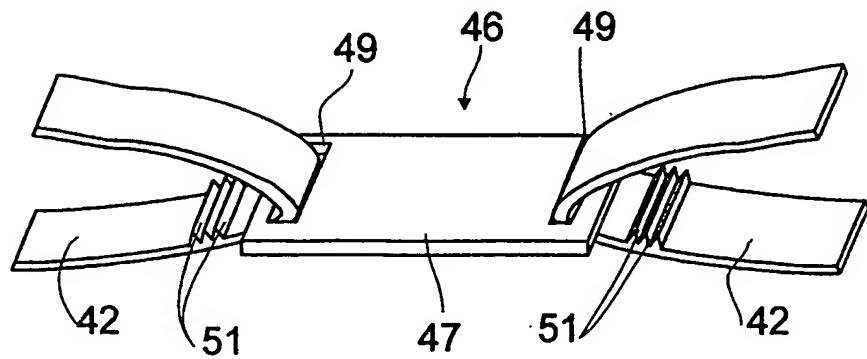


Fig. 6

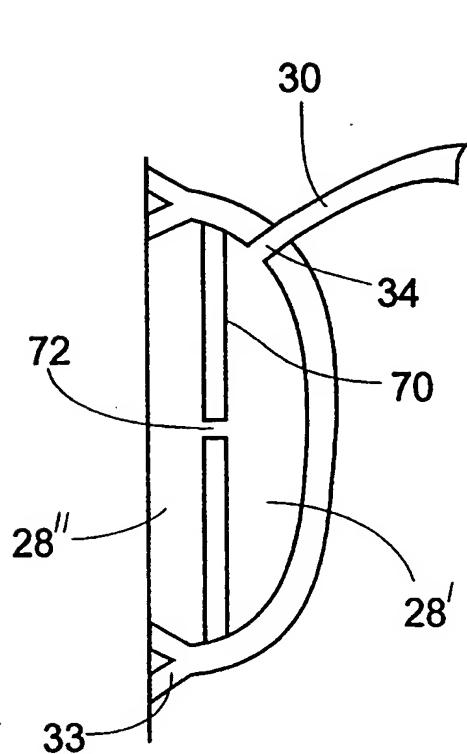


Fig. 10

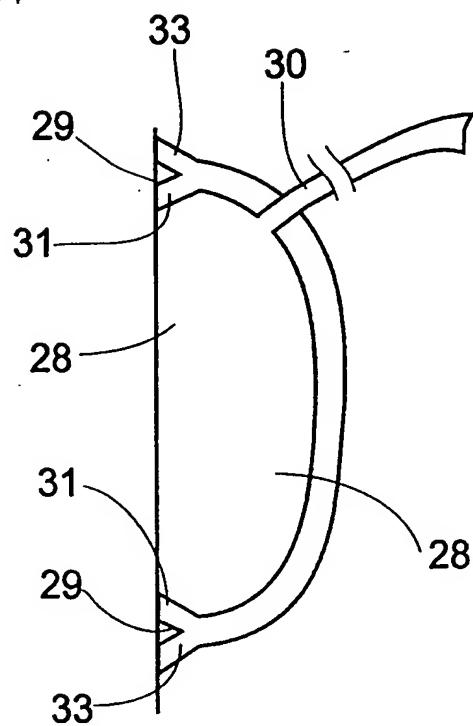


Fig. 8

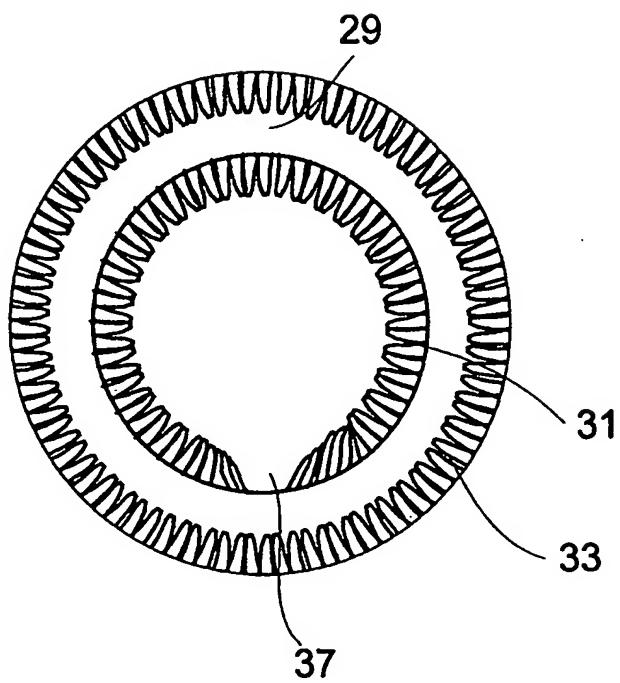


Fig. 10